IMPROVED LARVICULTURE OUTPUTS OF MARINE FISH, SHRIMP AND PRAWN

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LADIES AND GENTLEMEN,

- DEPENDABLE AVAILABILITY OF FRY, FINGERLINGS OR POSTLARVAE IS PROBABLY ONE, IF NOT THE SINGLE MOST CRITICAL FACTOR IN THE COMMERCIAL SUCCESS OF ANY AQUACULTURE INDUSTRY, BE IT WITH MARINE FISH SUCH AS TURBOT,
- OR WITH CRUSTACEANS SUCH AS THESE PENAEID SHRIMP.
- IN ECUADOR SHRIMP POSTLARVAE HAVE BEEN AND ARE STILL BEING COLLECTED FROM THE WILD BY THE BILLIONS PER YEAR, AND
- IN FACT THIS CHEAP SOURCE OF READILY AVAILABLE SEED HAS BEEN AT THE ORIGIN OF THE VERY SUCCESSFULL SHRIMP FARMING INDUSTRY IN ECUADOR.
- HOWEVER, WHEN WILD SEED PROVISIONS SUDDENLY DECREASED A NUMBER OF YEARS AGO, EXTENDED POND AREAS COULD NOT BE KEPT IN OPERATION.
- APPLYING INTENSIVE CULTURE TECHNIQUES AS SEEN HERE IN THE PHILIPPINES, FARMS NEED TO OPERATE AT MAXIMUM CAPACITIES IN ORDER TO SHOW GOOD PROFIT. THIS INVOLVES GUARANTEED PROVISIONS OF SHRIMP POSTLARVAE ON A YEARROUND BASIS.
- THIS DOESN'T MEAN THAT THE COLLECTION AND USE OF WILD FRY SHOULD BE DISCOURAGED, IN FACT FOR SOME SPECIES, SUCH AS HERE THE MILKFISH, ANNUAL PRODUCTION OF SEVERAL HUNDRED THOUSAND TONS OF PAN-SIZE FISH IS ENTIRELY DEPENDENT ON PROVISIONS OF WILD SEED.
- HOWEVER, FOR OTHER SPECIES LIKE MARINE SEABASS, AS SEEN HERE, OR DIFFERENT OTHER MARINE FISH SPECIES, GROWOUT TECHNIQUES IN CAGES FOR EXAMPLE HAVE PROVEN TO BE COMMERCIALLY ATTRACTIVE PROVIDED A REGULAR SUPPLY OF FRY CAN BE GUARANTEED.
- FOR MANY FISH AND CRUSTACEANS WITH AQUACULTURE POTENTIAL THIS CAN ONLY BE REALIZED BY THE DOMESTICATION OF THE SPECIES, WHICH INVOLVES THE DEVELOPMENT OF APPROPRIATE TECHNIQUES FOR CONTROLLED MATURATION AND LARVICULTURE.
- IN SALMON FOR EXAMPLE EGG PRODUCTION DOES NOT POSE MAJOR PROBLEMS,
- EARLY LARVAL DEVELOPMENT FURTHERMORE DOES NOT INVOLVE FEEDING PROBLEMS AS THE BABIES AT HATCHING CARRY A BIG YOLK SAC WITH ENOUGH FOOD RESERVES FOR THE FIRST THREE WEEKS OF THEIR DEVELOPMENT.
- ONCE YOLK IS CONSUMED AND EXOGENOUS FEEDING CAN START, LARVAE ALREADY HAVE A LARGE MOUTH AND
- CAN THRIVE ON FORMULATED FEEDS.
- THE STORY IS QUITE DIFFERENT WITH MOST OTHER MARINE FISH LARVAE WHERE EGG PRODUCTION MIGHT NOT POSE THE MAJOR PROBLEM BUT WHERE LARVAL SIZE AT HATCHING AND FIRST FEEDING IS AT THE ORIGIN OF FARMING DIFFICULTIES: SEEN HERE ARE SEABASS BABIES IN COMPARISON TO A SALMON LARVA.

- BASS, BREAM, TURBOT, MAHI MAHI AS SEEN HERE, AND MANY OTHER MARINE FISH WITH AQUACULTURE POTENTIAL ALL HAVE VERY LIMITED YOLK RESERVES AT HATCHING MOSTLY LASTING FOR NOT MORE THAN ONE OR TWO DAYS.
- AT FIRST FEEDING THEY STILL HAVE SMALL MOUTHS, OFTEN WITH AN OPENING SIZE OF LESS THAN 0.1 MILLIMETER.
- IN SHRIMP LARVAE FEED SIZE IS NOT THE ONLY PROBLEM, LARVAE FURTHERMORE PASS THROUGH DIFFERENT LARVAL STAGES EVENTUALLY CHANGING FROM A HERBIVOROUS FILTER-FEEDING BEHAVIOUR TO BECOME A CARNIVOROUS HUNTER.
- THE NATURAL DIET OF MANY AQUACULTURE FISH AND CRUSTACEAN SPECIES THUS CONSISTS OF A WIDE DIVERSITY OF PHYTOPLANKTON SPECIES (DIATOMS, FLAGELLATES, ETC.)
- AND ZOOPLANKTON ORGANISMS SUCH AS COPEPODS, CLADOCERANS, DECAPOD LARVAE, ETC. FOUND IN GREAT ABUNDANCE IN THE NATURAL PLANKTON,
- AND THUS PROVIDING THE BEST CHANCES TO MEET THE NUTRITIONAL REQUIREMENTS OF THE DEVELOPING LARVAE. RELYING ON THE COLLECTION OF WILD PLANKTON AS A LARVAL FOOD SOURCE IN INTENSIVE AQUACULTURE HAS PROVEN NOT TO BE A RELIABLE NOR A COMMERCIALLY FEASIBLE STRATEGY.

Fig 1

- OVER THE PAST TWO TO THREE DECADES TRIAL AND ERROR APPROACHES HAVE RESULTED IN THE ADOPTION OF SELECTED LARVICULTURE DIETS; THIS SCIENCE HAS BEEN VERY EMPIRICAL AND CAN A POSTERIORI ELEGANTLY BE SPLIT UP IN SELECTION CRITERIA TO BEST SUIT THE LARVAE'S REQUIREMENTS AND THE FARMERS RESTRICTIONS.
- TODAY THREE GROUPS OF LIVE DIETS ARE WIDELY APPLIED IN INDUSTRIAL LARVICULTURE OF MARINE FISH AND CRUSTACEANS:
  DIFFERENT SPECIES OF 2 TO 20 MICROMETER LARGE MICROALGAE, THE 50 TO 200 MIKROMETER ROTIFER BRACHIONUS PLICATILIS AND THE 200 TO 500 MIKROMETER BRINE SHRIMP ARTEMIA.
  IN RECENT YEARS DIFFERENT FORMULATIONS OF SUPPLEMENTATION AND SUBSTITUTION PRODUCTS HAVE BEEN ADDED TO THIS LIST.
- DIATOMS AND GREEN ALGAE ARE THE TWO DOMINANT GROUPS OF CULTURED MICROALGAE.
- FOOD SPECIES HAVE BEEN SELECTED ON THE BASIS OF THEIR MASS CULTURE POTENTIAL, CELL SIZE, DIGESTABILITY, AND OVERAL FOOD VALUE, MUCH MORE BY TRIAL AND ERROR THEN ANY OTHER SCIENTIFIC SELECTION PROCESS. IN FACT IT WAS ONLY IN RECENT YEARS YEARS THAT ONE COULD CONFIRM THAT DIFFERENCES IN FOOD VALUE BETWEEN CLOSELY RELATED SPECIES, F. EX. THE DIATOMS CHAETOCEROS AND PHAEODACTYLUM HAD MAINLY TO DO WITH DIFFERENCES IN LIPID COMPOSITION.
- THE MOST SUITABLE SPECIES STILL POSE MANY PROBLEMS FOR LARGE SCALE CULTURE, NOT THE LEAST WITH REGARD TO CONTAMINATION PROBLEMS. AS A RESULT MOST FARMS STILL APPLY LABOR INTENSIVE AND EXPENSIVE BATCH PRODUCTION SYSTEMS.
- EVEN WHEN PRODUCTION TARGETS CAN BE MAINTAINED WITH REGARD TO CELL NUMBERS PRODUCED, SHRIMP FARMERS FOR EXAMPLE HAVE EXPERIENCED TEMPORAL VARIATIONS IN ALGAL FOOD VALUES RESULTING IN INCONSISTENT HATCHERY OUTPUTS.

Fig. 2

- USING PENAEUS STYLIROSTRIS AS A TEST ORGANISM WE COULD DEMONSTRATE THAT THE CONTENT OF THE HIGHLY UNSATURATED FATTY ACIDS 20:5W3 AND 22:6W3 IN THE ZOEA DIET HAD A MAJOR IMPACT ON SURVIVAL AND GROWTH IN LATER STAGES, WHEN ANIMALS HAD ALREADY BEEN SWITCHED TO ANOTHER DIET.

Fig 3

- KNOWING THAT THE CONTENT OF THESE ESSENTIAL W3-HUFA'S CAN GREATLY VARY AMONG ALGAL SPECIES BUT EVEN FROM CULTURE TO CULTURE WITHIN A GIVEN SPECIES THE RATIONALE WAS PROVIDED TO LOOK FOR ALTERNATIVES OR SUPPLEMENTS TO LIVE MICROALGAE.
- DIFFERENT APPROACHES AND FORMULATIONS ARE BEING APPLIED AT COMMERCIAL LEVEL ALREADY, AND MANY NEW DEVELOPMENTS IN PRODUCING MORE COST-EFFECTIVE PRODUCTS ARE TO BE EXPECTED:
- MANIPULATED YEASTS, AS SEEN HERE,
- MICRO-ENCAPSULATED FEEDS
- AND DIFFERENT KINDS OF MICROPARTICULATE DIETS ARE GRADUALLY REDUCING THE NEED FOR AND MIGHT EVENTUALLY TOTALLY REPLACE THE MICROALGAE IN COMMERCIAL LARVICULTURE IN THE NEAR FUTURE.
- NEXT IS THE ROTIFER BRACHIONUS WHICH IS MOSTLY USED AS A STARTER DIET IN MARINE FISH LARVICULTURE.
- ITS CULTURE APPEARS TO BE SIMPLE, USING MICROALGAE OFTEN CHLORELLA SUPPLEMENTED WITH BAKERS' YEAST AS THEIR FEED.
- HOWEVER, MANY FISH HATCHERIES DO EXPERIENCE SIGNIFICANT PROBLEMS IN MAINTAINING LARGE CULTURES AND PRODUCING ON A PREDICTABLE BASIS THE MASSIVE NUMBERS OF ROTIFERS THAT ARE NEEDED TO FEED THE HUNDRED THOUSANDS TO MILLIONS OF BABY FISH THEY HAVE IN CULTURE. THE ROTIFERS' FOOD APPEARS TO BE ONE OF THE KEY ELEMENTS IN THE SUCCESSFULL MASS PRODUCTION OF ROTIFERS:
- FOR CONVENIENCE FRESH BAKERS' YEAST IS MOSTLY USED AS THE MAIN DIET INGREDIENT. HOWEVER, ITS FRESHNESS, A CRITERION WHICH IS HARD TO EVALUATE BY THE FARMER, CAN GREATLY INFLUENCE THE DIETARY VALUE OF THE YEAST FOR THE ROTIFERS, AND AS A CONSEQUENCE DETERMINE ROTIFER CULTURE SUCCESS. MANY FARMERS SUPPLEMENT THE BAKER'S YEAST WITH MICROALGAE, A PROCEDURE WHICH AT THE SAME TIME ENSURES AN INCREASE OF THE LEVEL OF ESSENTIAL FATTY ACIDS IN THE ROTIFERS; AS WE WILL SEE LATER, THIS OMEGA-3 HUFA-BOOSTING IS CRITICAL IN OPTIMIZING THE FOOD VALUE OF THE ROTIFERS FOR THE MARINE FISH LARVAE.
- DIFFERENT COMMERCIAL FORMULATIONS ARE USED FOR THIS BOOSTING WITH ESSENTIAL FATTY ACIDS AND OTHER COMPONENTS. THIS TREATMENT IS PERFORMED FROM 4 TO 24 HOURS PRIOR TO FEEDING THE ROTIFERS TO THE FISH LARVAE. A NEW TENDENCY IS TO SIMPLIFY PROCEDURES BY USING FEED-PRODUCTS FOR THE COMBINED CULTURE AND ENRICHMENT OF THE BRACHIONUS.
- OF THE LIVE DIETS USED IN LARVICULTURE, BRINE SHRIMP ARTEMIA NAUPLII CONSTITUTE THE MOST WIDELY USED SPECIES. ALTHOUGH ITS PRODUCTION AND USE APPEAR TO BE MOST SIMPLE,
- CONSIDERABLE PROGRESS HAS BEEN MADE IN THE PAST DECADE IN IMPROVING AND INCREASING ITS VALUE AS A LARVAL DIET. IT APPEARED INDEED THAT MANY SMALL DETAILS IN HATCHING PROCEDURES, WHICH IN THE PAST HAVE OFTEN BEEN OVERLOOKED, SUCH AS LIGHT, PH AND OTHERS, COULD SIGNIFICANTLY AFFECT CYST HATCHING OUTPUTS.
- THIS OPTIMIZATION IN ARTEMIA CYST USE WAS FURTHERMORE MADE POSSIBLE BY THE COMMERCIAL PROVISION OF HIGH QUALITY CYST PRODUCTS: ON ONE HAND NATURE HAS BEEN VERY GENEROUS IN RECENT YEARS NOT THE LEAST AT THE GREAT SALT LAKE IN UTAH,
- ON THE OTHER HAND INCREASED COMPETITION IN THE MARKET PLACE HAS ALSO CONTRIBUTED A LOT TO THE DEVELOPMENT OF IMPROVED METHODS FOR CYST CLEANING AND PROCESSING, RESULTING IN THE ADOPTION OF MORE RIGOROUS QUALITY CONTROL.

- A BETTER KNOWLEDGE OF ARTEMIA BIOLOGY ENABLED US TO DEVELOP METHODS FOR CYST DISINFECTION AND DECAPSULATION; THESE PROCEDURES ARE BEING APPLIED AT MOST LARGE FISH AND SHRIMP HATCHERIES TO STERILIZE THE CYSTS AND TO REMOVE THE SHELLS AS TO REDUCE THE PROBLEMS AT NAUPLIAR HARVEST.
- IN VIEW OF LABOR INVOLVED IN THE DAILY WORK OF CYST DECAPSULATION MANY HATCHERIES ARE NOW SWITCHING TO THE USE OF READY TO HATCH DECAPSULATED CYST PRODUCTS AVAILABLE ON THE MARKET.
- FOR A LONG TIME FARMERS HAVE OVERLOOKED THE FACT THAT ARTEMIA NAUPLII IN THEIR FIRST STAGE OF DEVELOPMENT CANN'T TAKE UP FOOD AND THUS CONSUME THEIR OWN ENERGY RESERVES. AT THE HIGH WATER TEMPERATURES WHICH ARE APPLIED FOR CYST INCUBATION, THE FRESHLY HATCHED ARTEMIA NAUPLII DEVELOP INTO THE SECOND LARVAL STAGE WITHIN A MATTER OF HOURS, EVENTUALLY LOOSING UP TO 30 PERCENT OF THEIR ENERGY RESERVES AND FOOD VALUE. THIS IS NOT ONLY A SIGNIFICANT FINANCIAL LOSS FOR THE FARMER AS HE HAS TO CONSUME UP TO 30 PERCENT MORE CYST PRODUCT TO PRODUCE THE SAME QUANTITY OF FOOD.

Fig 4

- HE IS FURTHERMORE FEEDING HIS FISH OR SHRIMP WITH A LESS SUITABLE PREY AS THE OLDER ARTEMIA HAVE GROWN BIGGER, SWIMM FASTER, ARE LESS VISIBLE, AND HAVE A REDUCED FOOD VALUE. THEREFOR RIGOROUS STANDARDIZATION OF HATCHING PROCEDURES IS A MUST, INCUBATING THE CYSTS AT CONSTANT WATER TEMPERATURES AND ALWAYS HARVESTING THE NAUPLII WHEN THEY ARE STILL IN THEIR MOST NUTRITIOUS STAGE. SOME HATCHERIES ALSO SWITCHED TO A PRACTICE OF DAILY MULTIPLE HATCHING AND SEPARATION PROCEDURES. - AN EASIER AND ALREADY COMMON PRACTICE NOWADAYS IS TO APPLY COLD STORAGE OF THE FRESHLY HATCHED NAUPLII IN CONCENTRATIONS OF SEVERAL MILLION NAUPLII PER LITER AT TEMPERATURES OF 5 TO 10 DEGREES CELSIUS. AERATION NEEDS TO BE PROVIDED IN ORDER TO PREVENT SUFFOCATION OF THE ARTEMIA WHICH BARELY MOVE AT THESE COLD TEMPERATURES AND EVENTUALLY SINK TO THE BOTTOM OF THE CONTAINER.

Fig 5

- APPLIED FOR PERIODS OF 24 HRS OR EVEN LONGER THE COLD STORED ARTEMIA REMAIN VIABLE WITHOUT CONSUMING THEIR ENERGY RESERVES. THIS ALLOWS THE FARMER NOT ONLY TO ENSURE THE AVAILABILITY OF A BETTER QUALITY PRODUCT BUT AT THE SAME TIME TO CONSIDER MORE FREQUENT FOOD DISTRIBUTIONS. THIS APPEARED TO BE BENEFICIAL FOR THE FISH AND SHRIMP LARVAE AS FOOD RETENTION TIMES IN THE LARVICULTURE TANKS CAN BE REDUCED AND HENCE GROWTH OF THE ARTEMIA IN THE CULTURE TANK CAN BE MINIMIZED; SHRIMP FARMERS AMONG YOU MIGHT RECALL THE DAYS THAT THEY WERE GROWING MORE ARTEMIA THAN SHRIMP IN THEIR LARVICULTURE TANKS...
- EASY HATCHING AND DISINFECTION PROCEDURES HOWEVER APPEARED NOT TO BE THE SOLE PARAMETERS IN ASSURING THE SUCCESS OF USING ARTEMIA AS A LARVAL FOOD SOURCE.

Fig 6

SEVERAL OTHER ARTEMIA CHARACTERISTICS CAN INFLUENCE THE SUITABILITY OF A PARTICULAR BRINE SHRIMP PRODUCT FOR ONE OR ANOTHER TYPE OF LARVICULTURE.

ONE OF THESE IS NAUPLIUS SIZE WHICH CAN GREATLY VARY FROM ONE GEOGRAPHICAL SOURCE OF ARTEMIA TO ANOTHER. THIS MIGHT NOT BE AN OBVIOUS CRITERION FOR THE HUMAN EYE, WE NEED TO REALIZE HOWEVER THAT THE LARVAE'S MOUTH SIZE IS SMALL AND THAT IN FISH FOR EXAMPLE THE PREY IS BEING SWALLOWED IN ONE BITE.

- USING THE MARINE SILVERSIDE MENIDIA AS A TEST-ORGANISM DR BENGTSON FROM THE UNIVERSITY OF RHODE ISLAND WAS ABLE TO ILLUSTRATE AN IMPORTANT CORRELATION BETWEEN ARTEMIA NAUPLIUS SIZE AND LARVAL MORTALITY DURING EARLY DEVELOPMENT: DATA REPRESENTED HERE ARE FOR 8 ARTEMIA STRAINS VARYING IN SIZE FROM 440 TO 560 MIKROMETER IN NAUPLIUS LENGTH; WITH THE LARGEST STRAINS OF ARTEMIA UP TO 50 PERCENT OF THE FISH CANNOT INGEST THIS PREY AND STARVE TO DEATH.

Fig 7

- THE EASY TO USE ARTEMIA FOOD, HOWEVER, HAD EVEN MORE MYSTERIES TO DISCLOSE. IN THE LATE SEVENTIES, EARLY EIGHTIES MANY FISH AND SHRIMP FARMERS WHICH JUST STARTED TO GO COMMERCIAL REPORTED UNEXPECTED PROBLEMS WHEN SWITCHING FROM ONE SOURCE OF ARTEMIA TO ANOTHER. JAPANESE, AMERICAN AND EUROPEAN RESEARCHERS LOOKED INTO THESE PROBLEMS, AND SOON CONFIRMED VARIATIONS IN NUTRITIONAL VALUE WHEN USING DIFFERENT GEOGRAPHICAL SOURCES OF ARTEMIA FOR FISH AND SHRIMP SPECIES, IN THIS CASE HERE WITH A MYSID SHRIMP.

Fig 8

- THE SITUATION BECAME MORE CRITICAL WHEN WE WERE ABLE TO PROVE THAT VERY SIGNIFICANT DIFFERENCES IN PRODUCTION YIELDS ARE OBTAINED WITH DISTINCT BATCHES OF THE SAME GEOGRAPHICAL ORIGIN OF ARTEMIA.

Fig 9

- TO MAKE A LONG STORY SHORT IT WAS PROVEN THAT THE CONCENTRATION OF THE ESSENTIAL FATTY ACID 20:5W3 IN THE ARTEMIA NAUPLII IS DETERMINING THE NUTRITIONAL VALUE OF THIS PARTICULAR BATCH OF ARTEMIA FOR THE LARVAE OF VARIOUS MARINE FISH AND CRUSTACEAN SPECIES. HERE WE CAN SEE THE RESULTS OBTAINED WITH DIFFERENT BATCHES OF THE SAME GEOGRAPHICAL ARTEMIA SOURCE, CONTAINING VERY DIFFERENT AMOUNTS OF 20:5W3 AND YIELDING PROPORTIONAL RESULTS IN GROWTH AND SURVIVAL OF MYSID SHRIMPS FED THESE ARTEMIA.

Fig 10

- IT IS IMPORTANT TO REALIZE THAT 20:5W3 LEVELS IN ARTEMIA CAN GREATLY VARY, EVEN FROM ONE BATCH TO ANOTHER WITHIN THE SAME STRAIN. CYST PRODUCTS FROM INLAND RESOURCES APPEAR TO BE MORE CONSTANT IN COMPOSITION BE IT HOWEVER AT SUBOPTIMAL LOW LEVELS. AS A RESULT CONCENTRATIONS OF THE W3-HUFA 20:5W3 NEED TO BE TAKEN INTO CONSIDERATION IN MAKING UP YOUR CHOICE OF THE MOST APPROPRIATE BATCH OF ARTEMIA CYSTS. THIS HAS LED TO THE IMPLEMENTATION BY AT LEAST ONE COMMERCIAL COMPANY OF QUALITY CERTIFICATES WHICH NOT THE LEAST BY THE EUROPEAN MARINE FISH FARMERS APPEAR TO BE VERY MUCH APPRECIATED.

Fig 11

- COMMERCIAL PROVISIONS OF HIGH W3-HUFA ARTEMIA CYSTS ARE LIMITED. THEIR USE HOWEVER, CAN (AND FOR MANY FISH SPECIES EVEN SHOULD) BE LIMITED TO THE FEEDING PERIOD WHEN SIZE OF THE PREY IS MOST CRITICAL. INDEED EVEN THE BEST NATURAL ARTEMIA PRODUCTS DO NOT MEET ALL THE NUTRITIONAL REQUIREMENTS OF THE PREDATOR LARVAE, MOST PARTICULARLY WITH REGARD TO THE OTHER ESSENTIAL FATTY ACID FOR MARINE ORGANISMS, NAMELY 22:6W3, WHICH IS NEVER AVAILABLE IN SIGNIFICANT AMOUNTS IN ARTEMIA CYSTS.
- IT IS FORTUNATE THAT ARTEMIA BECAUSE OF ITS PRIMITIVE CHARACTERISTICS FACILITATES A VERY CONVENIENT WAY TO MANIPULATE ITS BIOCHEMICAL COMPOSITION. SINCE ARTEMIA IS NON-SELECTIVE IN TAKING UP PARTICULATE MATTER ONCE IT HAS MOLTED INTO THE SECOND LARVAL STAGE, THAT MEANS ABOUT 8 HOURS FOLLOWING HATCHING, SIMPLE METHODS COULD BE DEVELOPED TO INCORPORATE ANY KIND OF PRODUCT INTO THE ARTEMIA PRIOR TO OFFERING IT AS A PREY TO THE PREDATOR LARVA. THIS METHOD OF BIOENCAPSULATION, ALSO CALLED ARTEMIA ENRICHMENT OR BOOSTING, IS WIDELY APPLIED AT MARINE FISH AND CRUSTACEAN HATCHERIES ALLOVER THE WORLD FOR ENHANCING THE NUTRITIONAL VALUE OF ARTEMIA WITH ESSENTIAL FATTY ACIDS.

Fig 12

- DIFFERENT COMMERCIAL FORMULATIONS SUCH AS MICROCAPSULES AND MICROPARTICULATE PRODUCTS ARE IN THE MARKETPLACE. THE HIGHEST ENRICHMENT LEVELS IN ARTEMIA AS WELL AS IN THE ROTIFER BRACHIONUS ARE OBTAINED WHEN USING EMULSIFIED CONCENTRATES WHICH ARE SEEN HERE AS AN OIL DROPLET IN THE DIGESTIVE TUBE OF THE ARTEMIA. TODAY W3-HUFA LEVELS IN ARTEMIA FOR EXAMPLE CAN BE INCREASED BY A FACTOR 10 TO 20 TIMES THE LEVELS FOUND IN NATURAL ARTEMIA PRODUCTS.
- THE USE OF W3-HUFA-ENRICHED ARTEMIA AS A MORE ADEQUATE FOOD SOURCE HAS WITHOUT ANY DOUBT BEEN AT THE ORIGIN OF A REAL BREAKTHROUGH IN THE LARVICULTURE OF MANY FISH SPECIES. FOR EXAMPLE FOR THE EUROPEAN BASS AND BREAM SPECIES, THE ADOPTION OF THIS BIO-ENCAPSULATION METHODOLOGY HAS BEEN A DECISIVE PUSH IN REALIZING THE COMMERCIAL LARVICULTURE OF THESE SPECIES.
- THE EFFECTS OF FEEDING W3-HUFA-ENRICHED ARTEMIA AND BRACHIONUS INDEED ARE SIGNIFICANT. EUROPEAN BASS DICENTRARCHUS LARVAE DIE OFF BEFORE DAY 35 WHEN FED HUFA-DEFICIENT FRESHLY-HATCHED ARTEMIA NAUPLII; SWITCHING TO ENRICHED ARTEMIA OF THE SAME BATCH RESULTS NOT ONLY IN INCREASED SURVIVAL BUT ALSO IN THE PRODUCTION OF BIGGER LARVAE WHICH BETTER RESIST STRESS CONDITIONS.

Fig 13

- SIMILAR OBSERVATIONS OF INCREASED SURVIVAL AND GROWTH WHEN FEEDING W3-HUFA-ENRICHED DIETS HAVE BEEN CONFIRMED FOR SEVERAL SPECIES OF PENAEID SHRIMP WHERE SOMETIMES EFFECTS OF DIET COMPOSITION ONLY COME TO EXPRESSION IN LATER STAGES.
- A GOOD ILLUSTRATION OF THIS IS THE RESISTANCE TO SALINITY STRESS IN PL-10 STAGES OF A BATCH OF P. MONODON LARVAE FED ON THREE DIFFERENT LARVAL DIETS THAT VARIED IN W3-HUFA LEVELS. SURVIVAL DIFFERENCES ON THE THREE DIETS WERE NOT SIGNIFICANT, HOWEVER DIFFERENCES IN PL-QUALITY ARE VERY PRONOUNCED. THIS CRITERION OF RESISTANCE TO SALINITY SHOCKS WHICH CAN EASILY BE APPLIED AT THE HATCHERY LEVEL IS NOW BEING USED AS A QUALITY CRITERION FOR DETERMINING THE APPROPRIATE TIME FOR PL-TRANSFER FROM THE HATCHERY TO THE PONDS.

Fig 14

- WITH THE FRESHWATER PRAWN MACROBRACHIUM HUFA-REQUIREMENTS OF THE LARVAE WERE ANTICIPATED NOT TO BE VERY CRITICAL IN VIEW OF THE FACT THAT THEY SPEND MOST OF THEIR LIFE IN FRESHWATER.
- THESE ASSUMPTIONS, HOWEVER, WERE LARGELY CONTRADICTED BY RECENT EXPERIMENTS IN WHICH WE USED ARTEMIA ENRICHED WITH DIFFERENT HUFA-EMULSIONS: THE MOST SPECTACULAR RESULTS WITH THE BIGGEST IMPACT FOR THE COMMERCIAL FARMER ARE THE MORE PRECOCIOUS AND MORE SYNCHRONOUS METAMORPHOSIS AS WELL AS THE HIGHER STRESS RESISTANCE OF THESE MACROBRACHIUM POSTLARVAE THAT HAD RECEIVED W3-HUFA-ENRICHED ARTEMIA IN THE LARVAL STAGES.
- WHEREAS FOR A NUMBER OF SPECIES LARVICULTURE OUTPUTS HAVE BEEN IMPROVED THANKS TO THESE DEVELOPMENTS IN NUTRITIONAL MANIPULATION OF THE LIVE FEEDS, WITH OTHER SPECIES SUCH AS MAHI-MAHI
- TURBOT,
- HALIBUT AND OTHERS, RESEARCH IS STILL IN PROGRESS TO BETTER DEFINE QUANTITATIVE HUFA REQUIREMENTS; IT APPEARS THAT FOR MANY SPECIES OF MARINE FISH WE HAVE NOT REACHED OPTIMAL DIETARY LEVELS YET IN BRACHIONUS AND ARTEMIA. HUFA'S MIGHT HAVE PROVEN MOST CRITICAL, OTHER LIPID CLASSES, PIGMENTS AND VITAMINS JUST TO MENTION THESE FEW MIGHT APPEAR EQUALLY IMPORTANT AND IN SOME SPECIES MAYBE MORE CRITICAL. - IN VIEW OF THE BETTER RESULTS OBTAINED WHEN USING NATURAL PLANKTON, FOR EXAMPLE CONSISTING OF MARINE COPEPODS IN CULTURING TURBOT, THE CHALLENGE REMAINS TO IDENTIFY THESE VITAL COMPONENTS IN THE COPEPODS IN ORDER TO HAVE THESE INCORPORATED IN THE CONVENIENT DIETARY SYSTEM CONSISTING OF BRACHIONUS AND ARTEMIA.

- IN THE PAST FIVE YEARS THE NUMBER AND CAPACITIES OF MARINE FISH AND CRUSTACEAN HATCHERIES HAVE ESCALATED ALLOVER THE WORLD. THE INTENSIFICATION OF HATCHERY ACTIVITIES HOWEVER BROUGHT ABOUT SEVERAL NEW PROBLEMS WHICH HADN'T SHOWN UP AT SMALL EXPERIMENTAL SCALE:
- SPINAL CORD DEFORMITIES AND ABSENCE OF SWIMM BLADDER INFLATION, LONG BLAMED TO BE GENETICAL DISORDERS, APPEARED TO BE CAUSED BY IMPERFECT ZOOTECHNICAL PROCEDURES: AN INVISIBLE OIL-FILM AT THE TANK'S SURFACE CAN HAMPER THE BABY FISH TO GULP AIR AND FILL THEIR SWIMM BLADDER; AS A RESULT THESE FISH NEED TO SPEND MORE SWIMMING EFFORTS TO STAY IN THE WATER COLUMN EVENTUALLY CAUSING SPINAL DEFORMITIES.
- THESE PROBLEMS ARE LARGELY OVERCOME TODAY BY APPLICATION OF MORE RIGOROUS WASHING PROCEDURES OF THE LIVE FOOD, ESPECIALLY AFTER ENRICHMENT WITH THE HIGH LIPID CONTAINING PRODUCTS.
- NEW EQUIPMENT AND MATERIALS WERE INTRODUCED IN THE HATCHERIES. WELDED WEDGE FILTERS AS SEEN HERE FROM ABOVE, ARE NOT ONLY VERY EFFICIENT IN WASHING AND CLEANING (LOOK AT THE MILKY SOLUTION IN THE DRAINAGE PART OF THE FILTER),
- AT THE SAME TIME THEY GUARANTEE THAT THE ARTEMIA ARE NOT PHYSICALLY DAMAGED DURING THIS PROCESS.
- OIL SKIMMERS INSTALLED IN THE FISH CULTURE TANK ENSURE FINAL PREVENTION OF THE BUILD-UP OF AN OIL FILM, WHICH MIGHT ALSO BE ENHANCED BY ALGAE METABOLITES WHEN APPLYING THE GREEN WATER TECHNIQUE.
- BACTERIAL AND VIRAL OUTBREAKS HAVE CAUSED ENORMOUS INTERFERENCES IN THE SUCCESSFUL INDUSTRIALIZATION OF FISH AND CRUSTACEAN LARVICULTURE. LACK OF BASIC HYGIENIC PRECAUTIONS HAS BEEN AND STILL IS AT THE ORIGIN OF MOST PROBLEMS.
- INSTEAD, ALL KINDS OF CHEMOTHERAPEUTICS ARE APPLIED AS PROPHYLACTICS. PRODUCTS WERE USED FOLLOWING TRIAL AND ERROR PROCEDURES, NOT BASED AT ALL UPON EXPERT ADVICE. A WIDE RANGE OF BROAD SPECTRUM ANTIBIOTICS BECAME ROUTINE APPLICATION IN SHRIMP AND MARINE FISH OPERATIONS. PRODUCTS SUCH AS CHLORAMPHENICOL, TETRACYCLINS, AND FURAZOLIDONE ARE OFTEN APPLIED AT DAILY DOSES UP TO 50 PPM AS FOR EXAMPLE IN THE CASE OF TURBOT. SHORT TERM BENEFITS SOON TURNED INTO DISASTERS. WORST AFFECTED HAS BEEN THE SHRIMP CULTURE INDUSTRY WERE AT TIMES AND PLACES ALL LARVICULTURE ACTIVITY HAD TO BE SUSPENDED.
- ALTHOUGH THERE IS STILL MUCH ROOM FOR IMPROVEMENT NOT THE LEAST BY A BETTER IDENTIFICATION AND DOCUMENTATION OF THE DISEASE PROBLEMS, BETTER PREVENTIVE MEASURES ARE BEING IMPLEMENTED: ROUTINE DISINFECTION PROCEDURES AND DRY-OUTS IN- BETWEEN TWO TO THREE CONSECUTIVE SHRIMP LARVICULTURE RUNS ARE WIDELY ADOPTED NOW AND HAVE RESULTED IN MORE PREDICTABLE HATCHERY OUTPUTS.
- IN MARINE FISH LARVICULTURE IT APPEARS THAT MICROBIAL PROBLEMS ARE LESS CRITICAL IN THOSE HATCHERIES THAT ARE OPERATING RECIRCULATION SYSTEMS USING BIOLOGICAL FILTERS. THERE IS GREAT NEED INDEED TO DOCUMENT THE MICROBIAL ENVIRONMENT IN FISH AND CRUSTACEAN HATCHERIES NOT ONLY AT CRITICAL MOMENTS BUT ALSO WHEN OUTPUTS ARE OPTIMAL, THIS IN ORDER TO REVEAL SPECIES AND QUANTITIES THAT ARE TO BE CONSIDERED PROBIONTS AND PATHOGENS.
- AS WAS RECENTLY DEMONSTRATED THE BIOENCAPSULATION METHODOLOGY WITH ARTEMIA AND BRACHIONUS CAN ALSO BE CONSIDERED FOR MORE EFFECTIVE TRANSFER OF THERAPEUTICS THROUGH ORAL ADMINISTRATION OF ANTIBIOTICS.

- IN THE PAST DECADE MARINE FISH AND CRUSTACEAN HATCHERIES HAVE EVOLVED FROM HIT AND MISS VENTURES INTO PROFITABLE VENTURES. WITH MANY FISH SPECIES THE LARVICULTURE INDUSTRY HAS NOT YET REACHED THE STATE OF COMPETITIVE MATURITY.
- IN EUROPE FOR EXAMPLE THE SITUATION IS ARTIFICIAL BECAUSE FRY OUTPUTS CANNOT MEET PRESENT DEMANDS.
- AS A RESULT HATCHERIES CAN SELL THEIR FINGERLINGS AT PRICES THAT RANGE FROM 1 US $ PER INDIVIDUAL FINGERLING OF BASS AND BREAM UP TO 4 US $ PER TURBOT FRY. MARGINS OF PROFIT ARE HIGH. HOWEVER, ONE SHOULD NOT FORGET THAT MANY OF THESE HATCHERIES HAVE LOST MONEY FOR YEARS WHEN THEY WERE PIONEERING MARINE FISH LARVICULTURE. THE NUMBER OF MARINE FISH HATCHERIES IS INCREASING VERY FAST IN EUROPE AND THE ONES ALREADY IN OPERATION ARE STEADILY INCREASING THEIR CAPACITIES. THE SITUATION WILL SOON TURN, SIMILARLY TO WHAT HAS BEEN EXPERIENCED IN RECENT YEARS WITH THE PRICES OF SALMON SMOLTS AND PENAEID SHRIMP POSTLARVAE.
- IN CERTAIN COUNTRIES LIKE TAIWAN, THAILAND, ECUADOR, ETC. MARKET PRICES OF PENAEUS MONODON AND VANNAMEI CRASHED FROM A YEARLONG MAGIC PRICE OF 20 US $ PER THOUSAND TO EXTREMILY COMPETITIVE PRICES OF A FEW DOLLARS ONLY.
- BIG HATCHERIES WITH HIGH INVESTMENT AND OVERHEAD COSTS MAY ONLY REMAIN VIABLE WHEN THEY CAN OPERATE ON AN ANNUAL BASIS AND AT MAXIMAL EFFICIENCY; INDEED SOME OF THE BIG OPERATIONS AS SEEN HERE IN ECUADOR MANAGE TO YIELD SURVIVAL RATES EXCEEDING 80 PERCENT AT HARVEST OF THE PL'S.
- BACKYARD HATCHERIES ARE A PECULIAR PHENOMENON AS THESE ARE MOSTLY HIT AND MISS OPERATIONS. THEY ARE MANAGED WITH LIMITED EXPERTISE, MOSTLY UNDER POOR WATER QUALITY AND HYGIENIC STANDARDS. NONETHELESS THEY HAVE BECOME MORE AND MORE IMPORTANT AND MUSHROOMED DURING THE LAST COUPLE OF YEARS INTO THE THOUSANDS IN SOME SE-ASIAN COUNTRIES.
- AS THESE FAMILY ACTIVITIES INVOLVE MINIMAL OPERATIONAL COSTS THEY CAN AFFORD LOW SUCCESS RATES AND STILL REMAIN PROFITABLE AT PL-PRICES WHICH ARE BEYOND PRICE LIMITS FOR PROFITABLE PRODUCTION BY THE LARGE HATCHERIES. HOWEVER, THEY IMPOSE CONSIDERABLE RISKS FOR TOTAL COLLAPSES OF LOCAL AQUACULTURE ACTIVITIES AS WAS THE CASE WITH THE ONE TIME VERY SUCCESSFUL SHRIMP FARMING INDUSTRY IN TAIWAN.
- IN ORDER TO BECOME A STABILIZED INDUSTRIAL ACTIVITY THAT MEETS THE REQUIREMENTS OF LOCAL GROWOUT CAPABILITIES THE LARVICULTURE OF MARINE FISH AND CRUSTACEANS NEEDS TO FURTHER IMPROVE ITS OUTPUTS. WITH SURVIVAL RATES IN MARINE FISH LARVICULTURE RARELY REACHING 20 TO 30 PERCENT, IT IS CLEAR THAT THERE IS STILL MUCH ROOM FOR IMPROVEMENT AND INCREASED COST-EFFECTIVENESS:
- WE CONSIDER THAT IN A SHORT TERM FRAME THE FOLLOWING FIELDS NEED MORE EXPLORATION: HOW CAN EGG QUALITY BE BETTER DEFINED AND CONTROLLED, WE STILL LACK MUCH KNOWLEDGE ABOUT QUALITATIVE AND QUANTITATIVE NUTRITIONAL REQUIREMENTS IN MOST SPECIES, TOO LIMITED ATTENTION HAS BEEN PAID TO ZOOTECHNICAL ASPECTS IN RELATION TO UPSCALING, AUTOMATION, RECIRCULATION SYSTEMS, INTENSIVE VERSUS EXTENSIVE SYSTEMS, ETC. BETTER UNDERSTANDING OF THE MICROBIAL ENVIRONMENT IN THE HATCHERY AS WELL AS THE LARVAL IMMUNE SYSTEM WILL ALLOW BETTER MANAGEMENT WITH REGARD TO DISEASE PREVENTION AND CONTROL.

- WE WANT TO FINISH THIS PRESENTATION WITH A LAST REMARK REGARDING FEEDING STRATEGIES IN LARVICULTURE, MORE PARTICULARLY THE FUTURE OF LIVE FEEDS VERSUS FORMULATED FEEDS. OFF THE SHELF DRY PRODUCTS ARE BEING DEVELOPED AND COMMERCIALIZED AS A MUCH MORE USER FRIENDLY APPLICATION FOR THE FARMER. WITH SOME SPECIES SUCH AS PENAEID SHRIMP WE ARE CLOSE TO THE DAY OF REDUCING LIVE ALGAE AND ARTEMIA FEEDING TO VIRTUAL ELIMINATION FROM THE HATCHERY OPERATION.
  OTHER SPECIES SUCH AS MARINE FISH SPECIES IMPOSE MUCH MORE CONSTRAINTS THAN SHRIMP NOT ONLY IN TERMS OF NUTRITIONAL REQUIREMENTS BUT ALSO WITH REGARD TO PHYSICAL PROPERTIES OF THE FEED, SUCH AS WATER STABILITY, BUOYANCY, PALATABILITY, ETC.). APPROPRIATE PROCESS TECHNOLOGIES WILL CERTAINLY BE DEVELOPED BUT THEIR COMMERCIAL APPLICABILITY AND PRICE COMPETITIVENESS MIGHT NOT BE OBVIOUS.
- FEEDING STRATEGIES IN HATCHERIES OF MARINE FISH AND CRUSTACEANS WILL PROBABLY NEVER TURN INTO WORLDWIDEL STANDARDIZED BLUEPRINT METHODS BECAUSE OF SPECIES DIFFERENCES AND GEOGRAPHICAL DISCREPANCIES. THE COST-EFFECTIVENESS OF LIVE AND FORMULATED FEEDS WILL DICTATE THEIR PROPORTIONAL USE.

fig. 1.

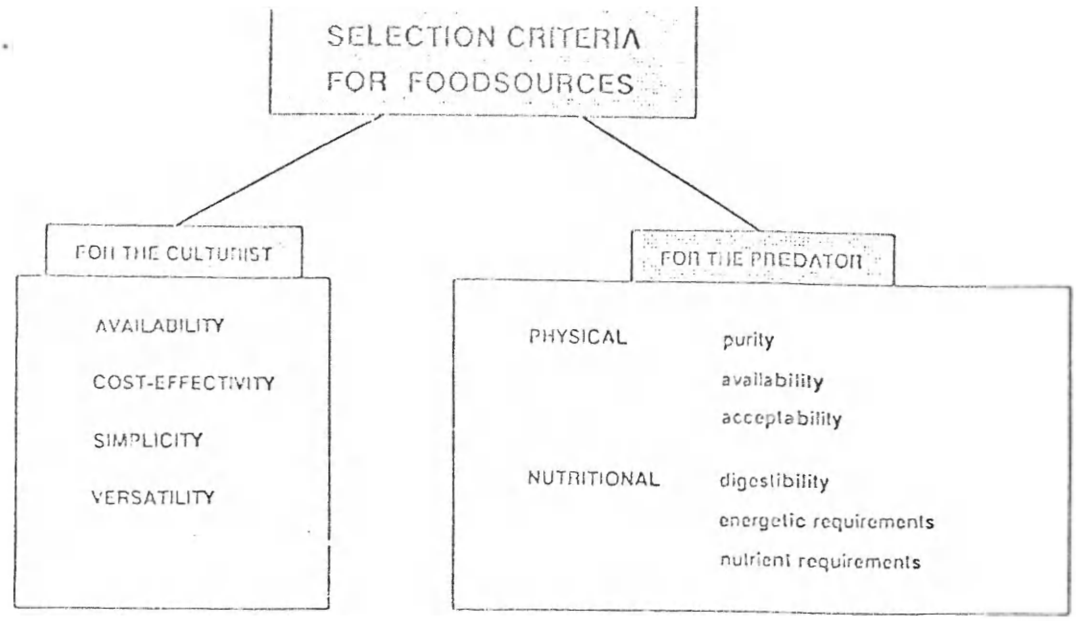

SELECTION CRITERIA
FOR FOODSOURCES
FOR THE CULTURIST
AVAILABILITY
COST-EFFECTIVITY
SIMPLICITY
VERSATILITY
FOR THE PREDATOR
PHYSICAL
purity
availability
acceptability
NUTRITIONAL
digestibility
energetic requirements
nutrient requirements

fig. 2

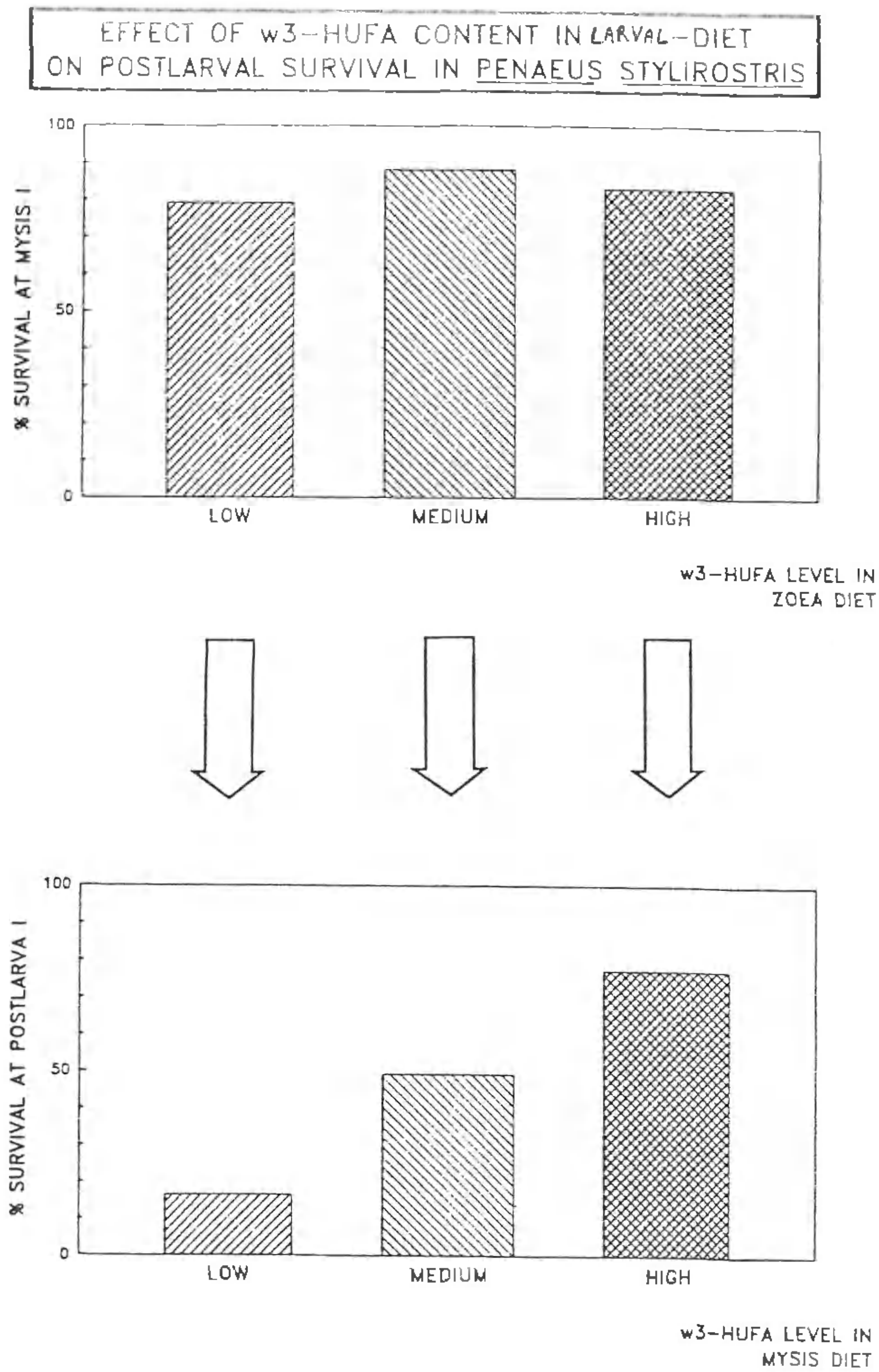
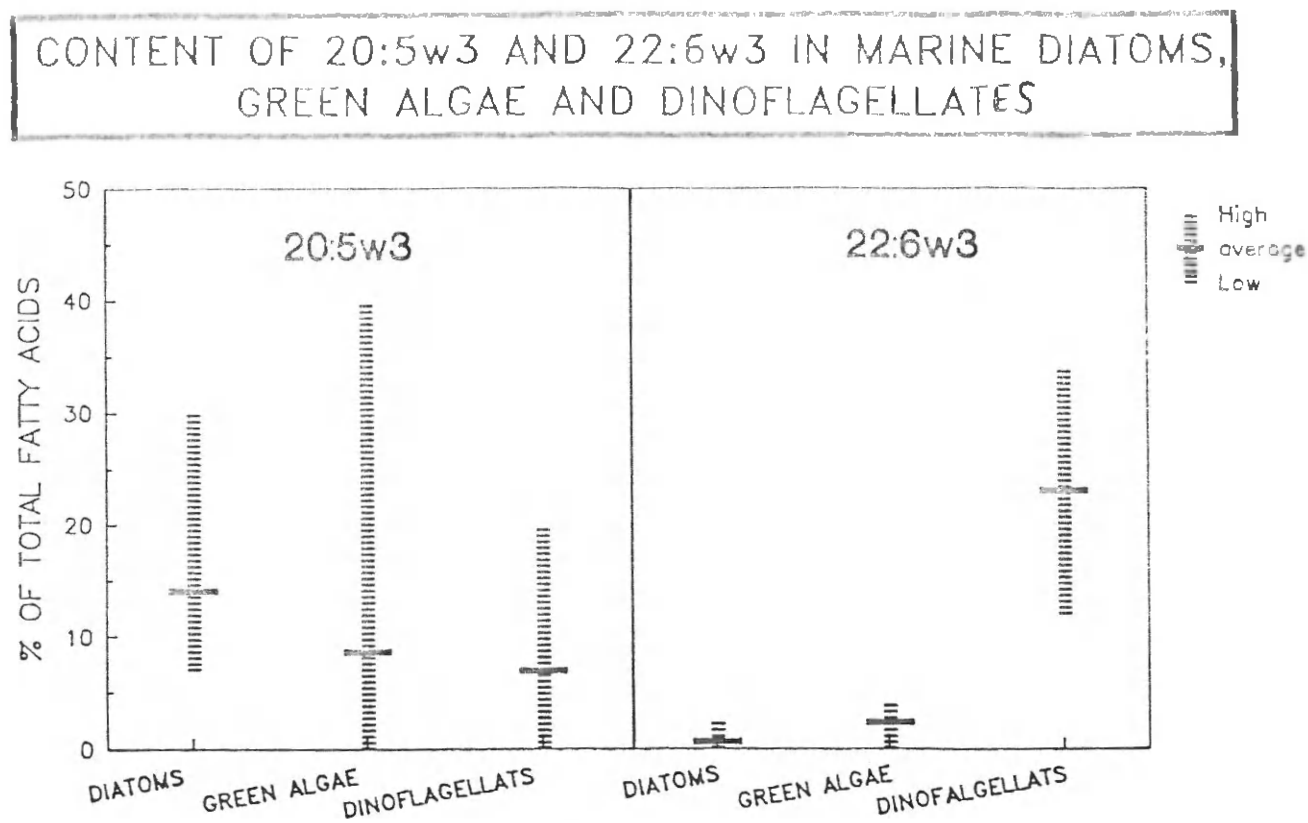

EFFECT OF w3-HUFA CONTENT IN LARVAL-DIET
ON POSTLARVAL SURVIVAL IN PENAEUS STYLIROSTRIS
% SURVIVAL AT MYSIS I
100
50
0
LOW
MEDIUM
HIGH
w3-HUFA LEVEL IN
ZOEA DIET
% SURVIVAL AT POSTLARVA I
100
50
0
LOW
MEDIUM
HIGH
w3-HUFA LEVEL IN
MYSIS DIET

Fig. 3



Data from Pohl (1982), Seto et. al. (1984), Ben-Amotz et.al. (1985), Olsen et. al. (1989)

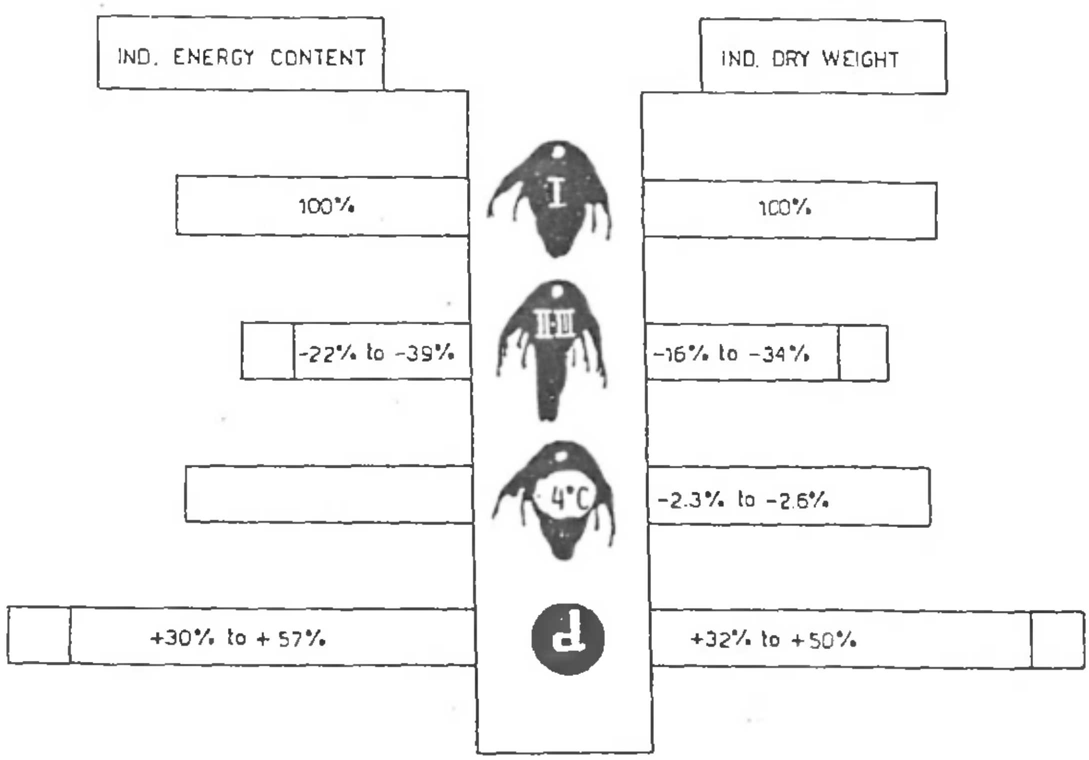
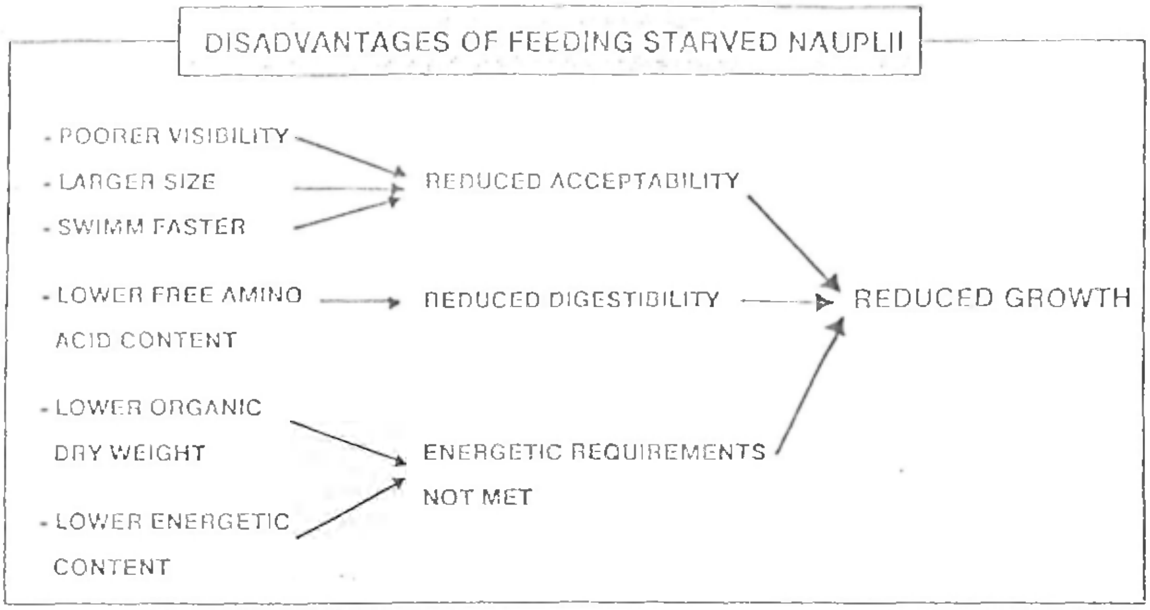


Fig. 4. -Schematic drawing of decrease of individual energy content and dry weight in instar II-III metanauplii, 24 h cold stored nauplii, and decapsulated cysts as compared to freshly hatched instar I *Artemia* nauplii (modified from Léger *et al.*, 1986b).

Fig.5



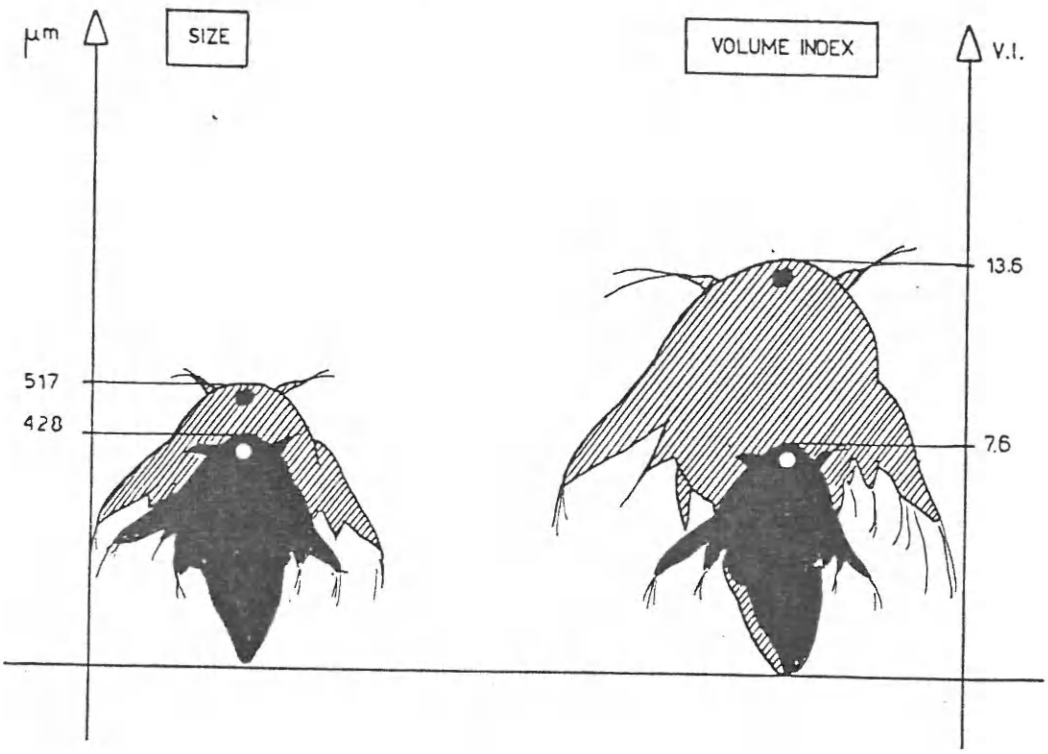


Fig.6. Variation in size and volume index between Artemia strains from different geographical origin (after Vanhaecke and Sorgeloos, 1980)

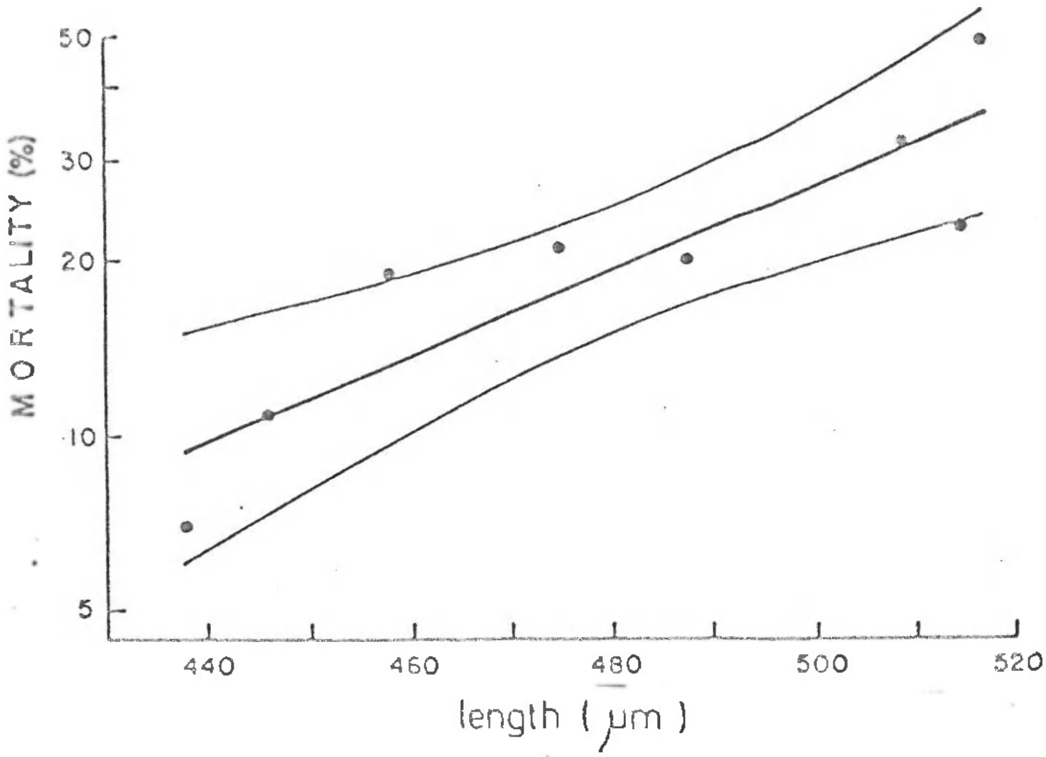


Fig. 7.—Correlation of mortality rate of *Menidia menidia* larvae and naupliar length of *Artemia* fed to the larvae: ln mortality $= 15 \cdot 103 + 0 \cdot 0168 \times$ length, or mortality $= 0 \cdot 006 \times e^{0 \cdot 0168 \times \text{length}}$, $r^2 = 0 \cdot 792$; after Beck & Bengtson, 1982.

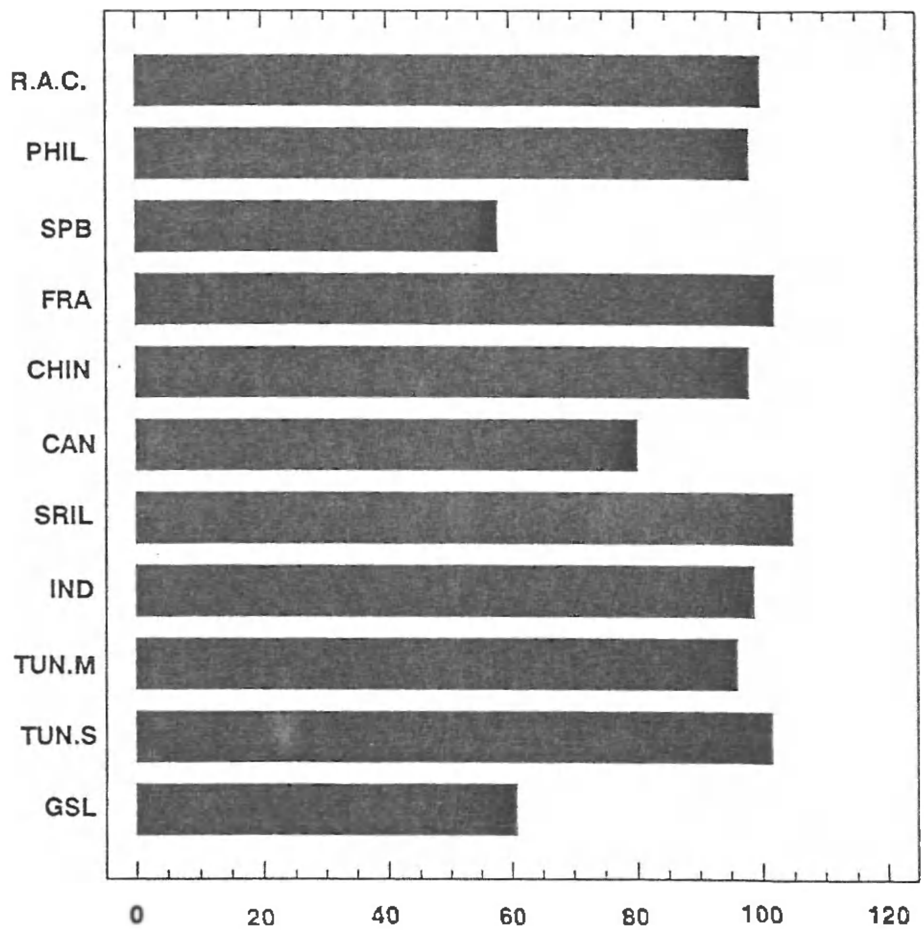


Fig. 8. Survival of Mysidopsis bahia larvae fed different geographical Artemia strains (expressed as percentage of the control treatment fed with Reference Artemia Cysts; after Léger, 1989)

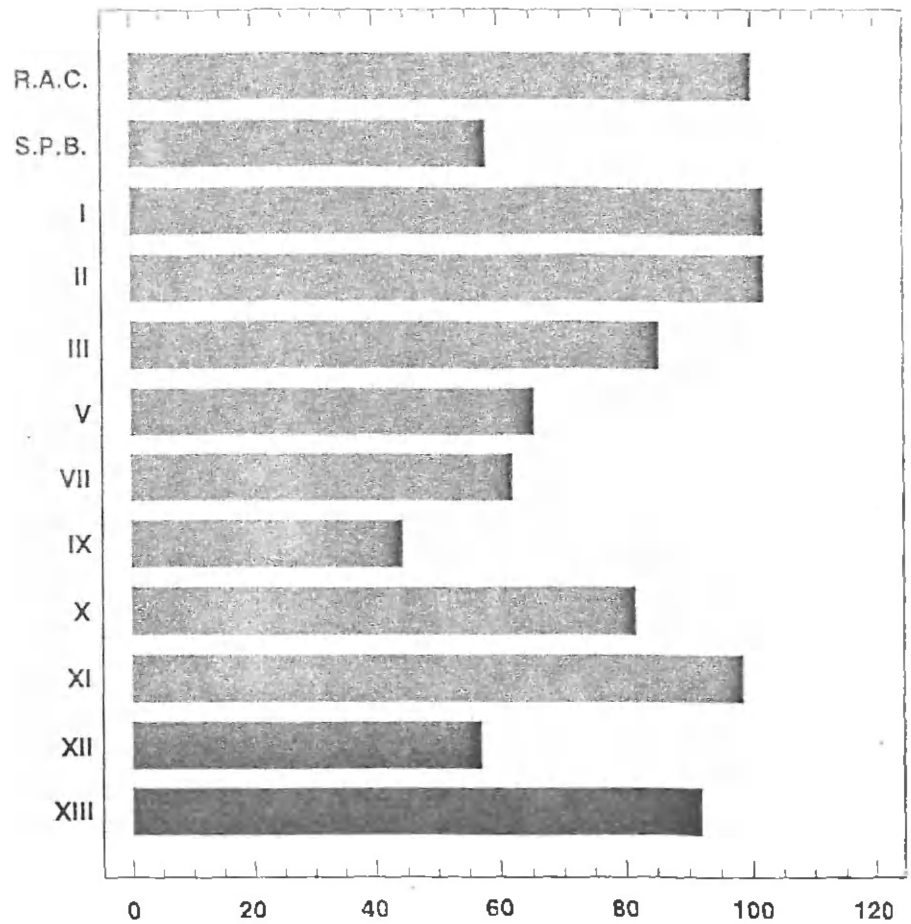


Fig. 9. Survival of Mysidopsis bahia larvae fed different batches of San Francisco Bay Artemia (expressed as percentage of the control treatment fed with Reference Artemia Cysts; after Léger, 1989)

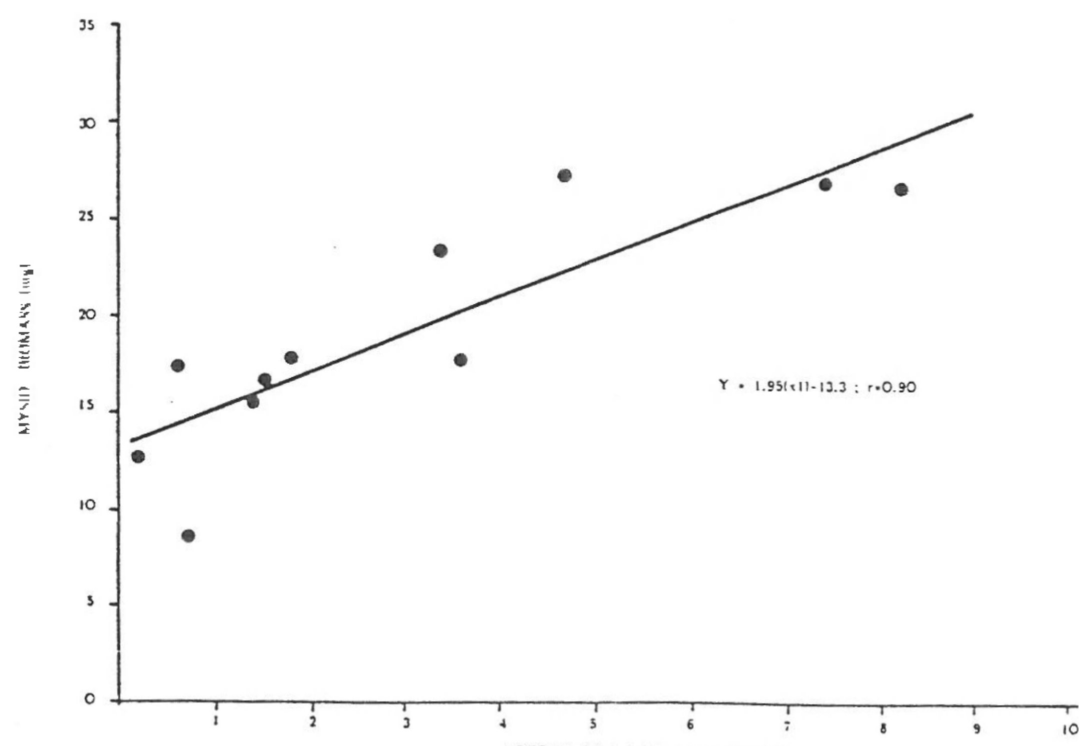


Fig. 10. Linear relationship between the 20:5ω3 content of several *Artemia* collections from San Francisco Bay origin and the biomass of mysids to which the *Artemia* were fed (data from Léger *et al.*, 1987).

Fig 11

Intra-strain variability of 20:5ω3 content in *Artemia*
Data represent the range (area percent) and coefficient
of variation of data as compiled by Léger *et al.* 1986, 1987

Artemia geographical strain	20:5ω3 range (area %)	coefficient of variation (%)
USA – California : San Francisco Bay	0.3-13.3	78.6
USA – Utah Great Salt Lake (south arm)	2.7- 3.6	11.8
USA – Utah Great Salt Lake (north arm)	0.3- 0.4	21.2
Canada-Chaplin Lake	5.2- 9.5	18.3
Brazil-Macau	3.5-10.6	43.2
PR China-Tientsin	1.3-15.4	50.5

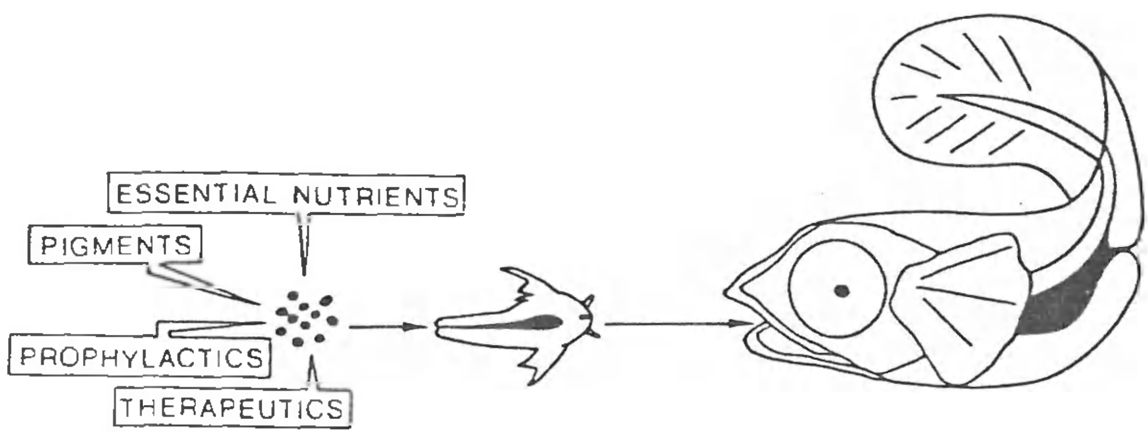


Fig. 12 Schematic outline of the technique using *Artemia* as a carrier for various nutritional, prophylactic and therapeutic components.

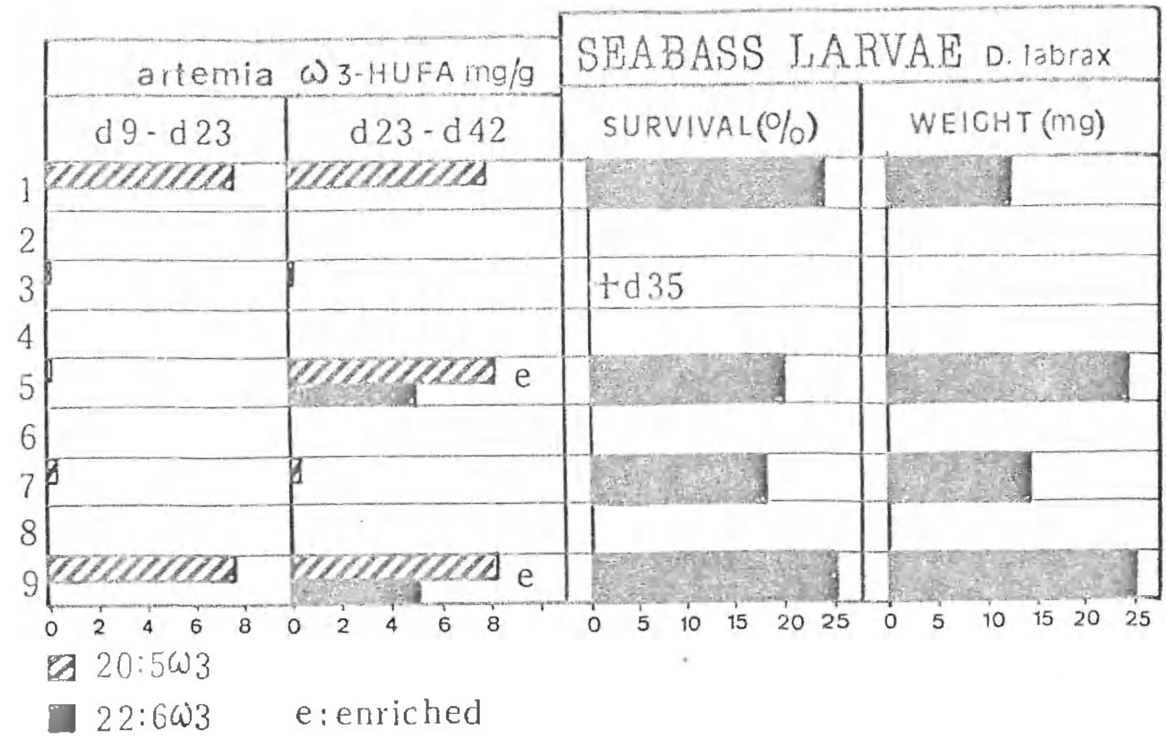
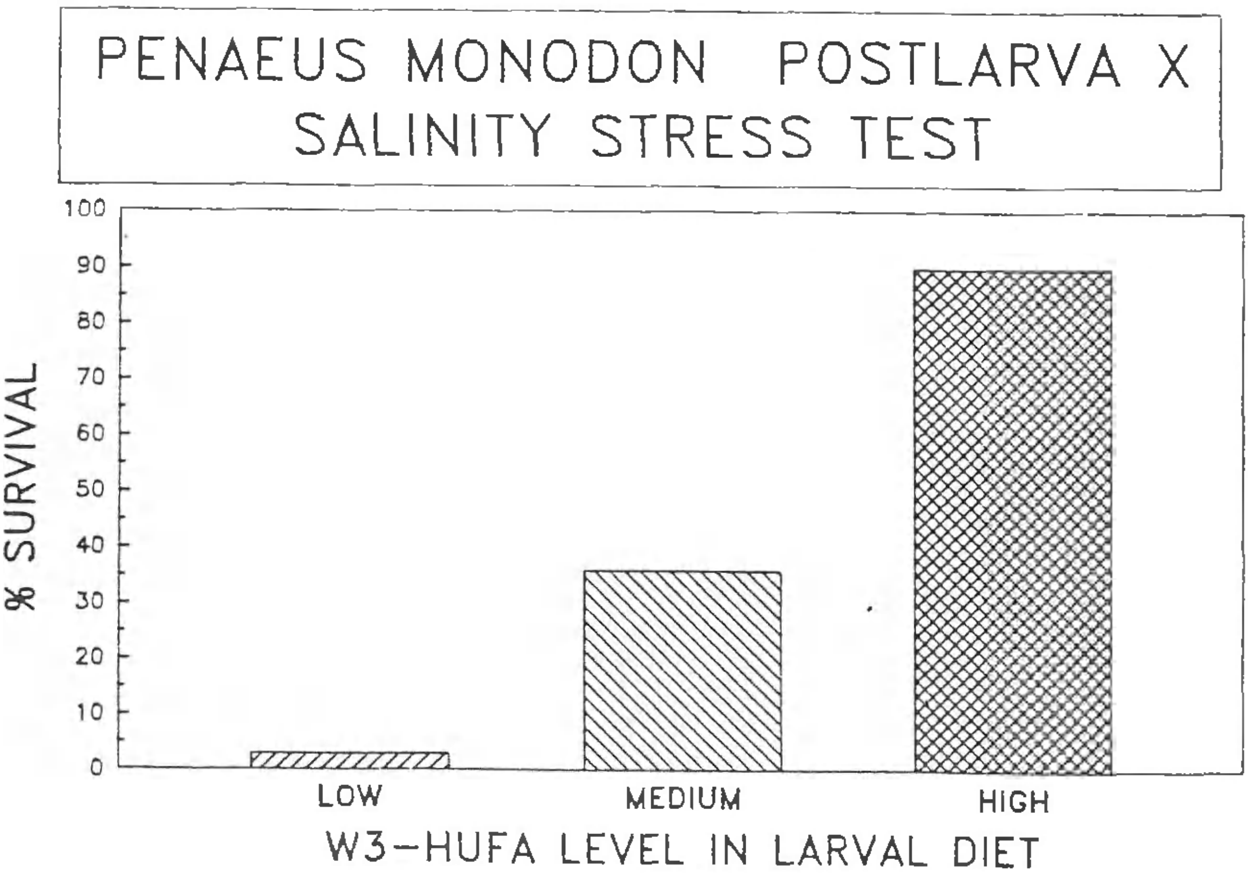


Fig. 13. Survival and weight of European seabass Dicentrarchus labrax larvae fed from day 9 to 23 and from day 23 to 42 with different Artemia batches, enriched or non-enriched with the w-3 HUFA's 20:5w3 and 22:6w3 (after Franicevic et al., 1987)

Fig. 14



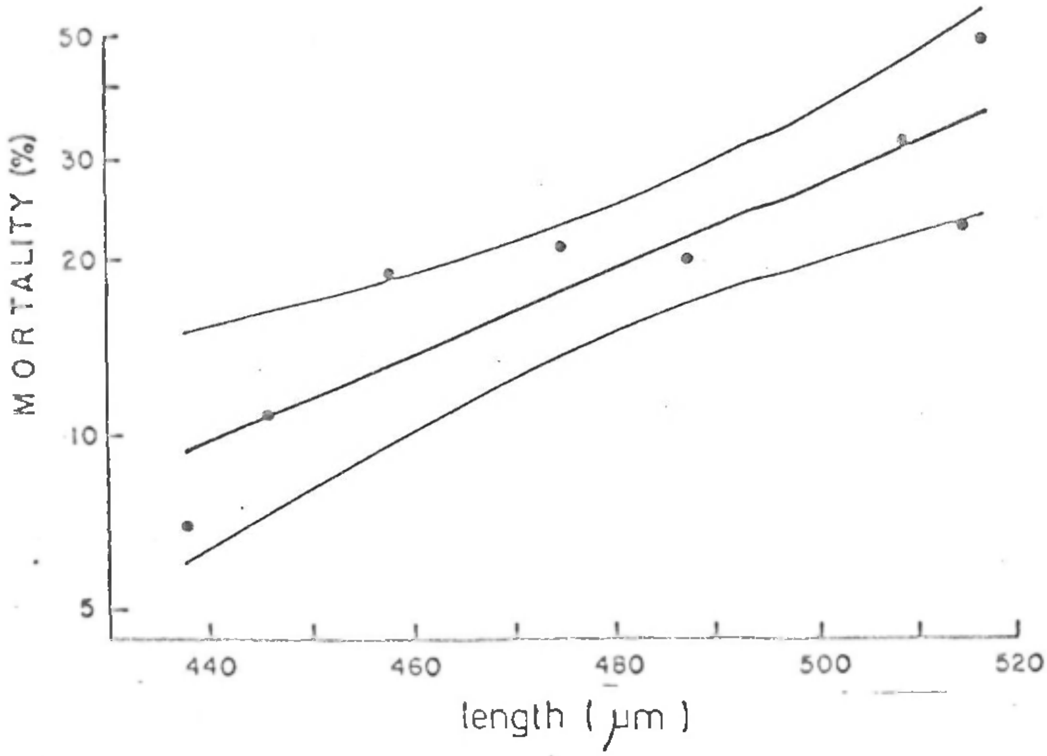


Fig. 7 .—Correlation of mortality rate of *Menidia menidia* larvae and naupliar length of *Artemia* fed to the larvae: ln mortality = 15·103 + 0·0168 × length, or mortality = 0·006 × $e^{0\cdot 0168}$ × length, $r^2 = 0\cdot 792$; after Beck & Bengtson, 1982.

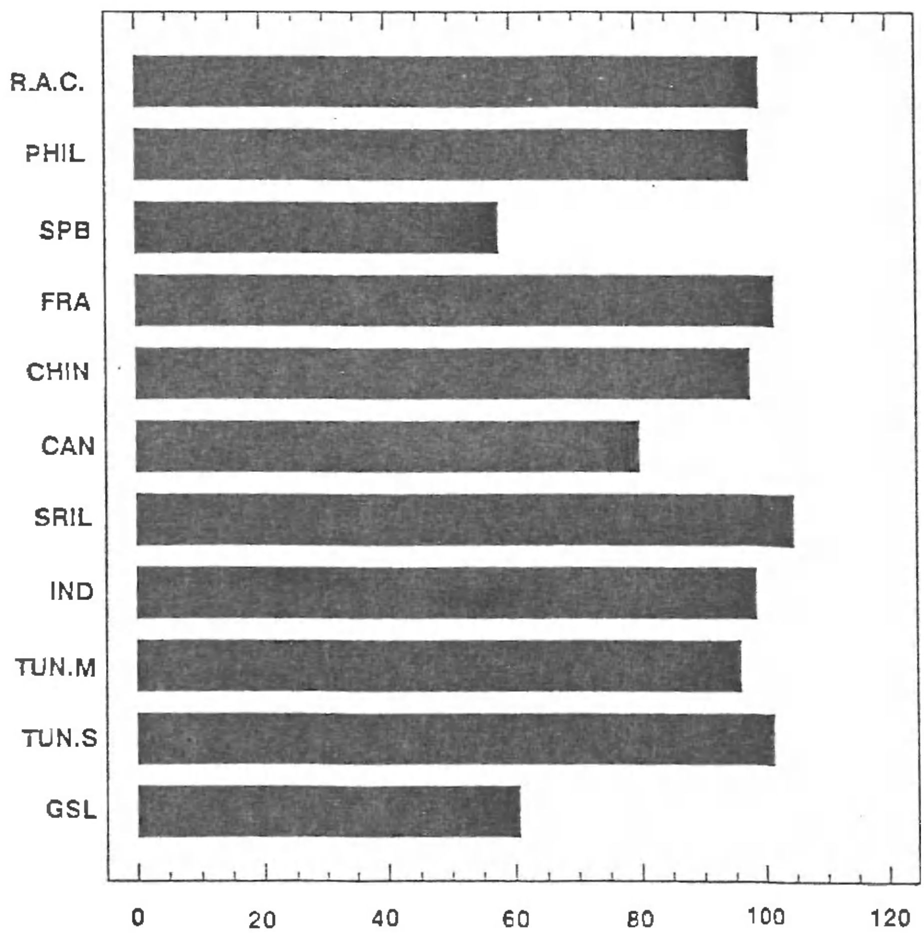
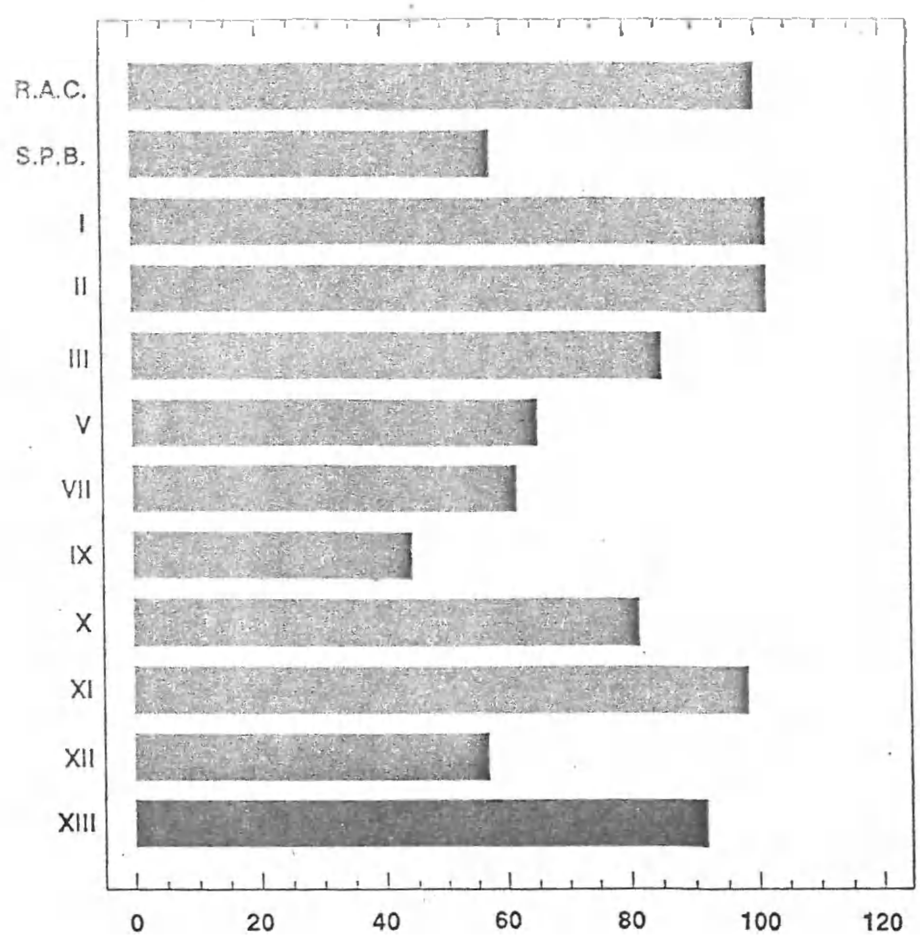


Fig. 8 . Survival of Mysidopsis bahia larvae fed different geographical Artemia strains (expressed as percentage of the control treatment fed with Reference Artemia Cysts; after Léger, 1989)



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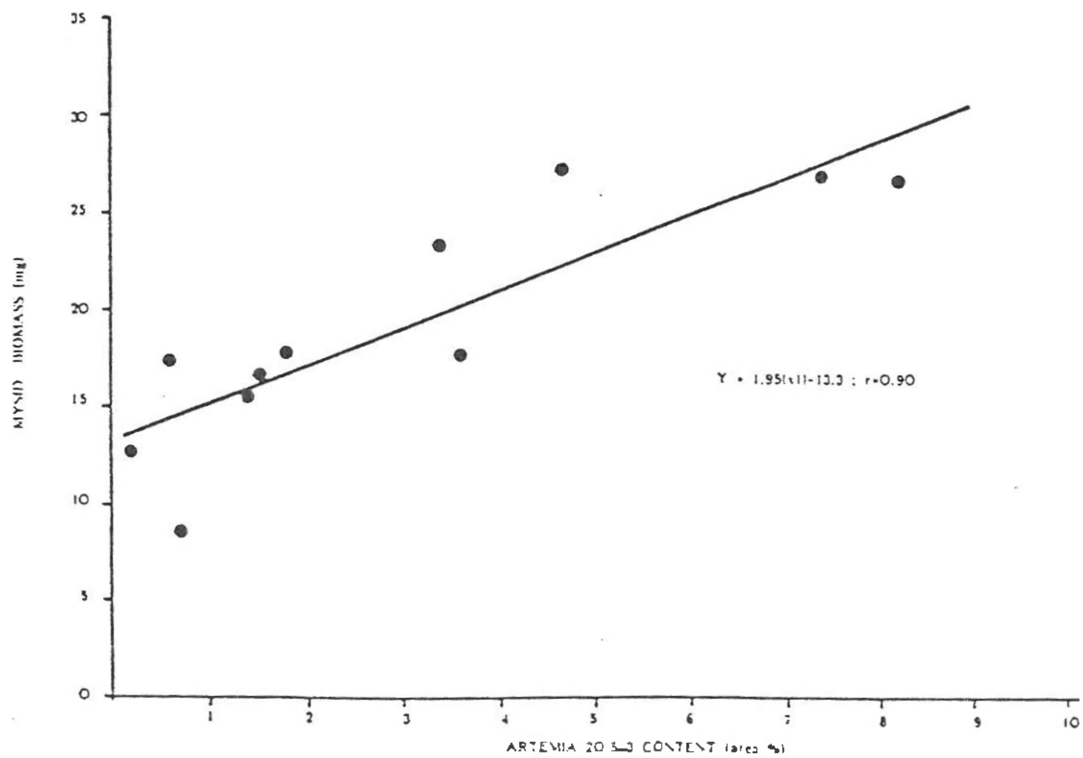

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